

37. Copper nitrate decomposes when heated according to the following equation:



If 1.80g of copper nitrate is heated and the gases collected at a temperature of 22°C and 105kPa:

a. What volume (in dm^3) of oxygen is collected?

$$\frac{1.80\text{g Cu}(\text{NO}_3)_2}{187.57\text{g}} \times \frac{1\text{mol Cu}(\text{NO}_3)_2}{2\text{mol Cu}(\text{NO}_3)_2} = 0.004798\text{mol O}_2$$

$$V = \frac{nRT}{p} = \frac{0.004798\text{mol} \times 8.31\text{kg m}^2 \text{s}^{-2} \text{mol}^{-1} \text{K}^{-1} \times 295\text{K}}{105\text{kPa} \times 10^3\text{Pa} \times 10^{-3}\text{m}^3} = 0.112\text{dm}^3 \text{O}_2$$

b. What is the total volume of gas collected in cm^3 ?

$$\frac{0.112\text{dm}^3 \text{O}_2}{1\text{dm}^3 \text{O}_2} \times \frac{4\text{dm}^3 \text{NO}_2}{1\text{dm}^3 \text{O}_2} = 0.448\text{dm}^3 \text{NO}_2 + 0.112\text{dm}^3 = 0.560\text{dm}^3 \text{ tot. volume} \quad (560\text{cm}^3)$$

38. When a certain mass of Mn_2O_7 decomposed, it produced 127.8cm^3 of oxygen measured at 18°C and $1.00 \times 10^5 \text{ Pa}$. What mass of Mn_2O_7 decomposed?



$$n_{\text{O}_2} = \frac{PV}{RT} = \frac{1.00 \times 10^5 \text{ Pa} \times 127.8 \text{ cm}^3}{8.31 \text{ kg m}^2 \text{s}^{-2} \text{mol}^{-1} \text{K}^{-1} \times 291\text{K}} = 0.00528\text{mol O}_2$$

$$\frac{0.00528\text{mol O}_2}{3\text{mol O}_2} \times \frac{2\text{mol Mn}_2\text{O}_7}{1\text{mol Mn}_2\text{O}_7} \times 221.88\text{g} = 1.0782\text{g}$$

39. What mass of sodium sulfate (Na_2SO_4) must be used to make up 250cm^3 of a 0.100mol dm^{-3} solution?

a. What is the concentration of sodium ions in the solution?

$$[\text{Na}^+] = \frac{\text{mol}}{\text{L}} \quad \text{mol} = M \cdot L = 0.100\text{mol dm}^{-3} \times 0.250\text{dm}^3 = 0.0250\text{mol}$$

$$4 - 0 - 1 \text{ to } - 0. - 90 \text{ to } 3.55\text{g}$$

$$\text{a) } \frac{0.100\text{mol Na}_2\text{SO}_4}{\text{dm}^3} \times \frac{2\text{mol Na}^+}{1\text{mol Na}_2\text{SO}_4} = 0.200\text{mol Na}^+ \text{ dm}^{-3}$$

40. Work out the numbers of moles present in the following solutions:

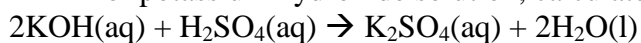
a. 20.0cm^3 of 0.220mol dm^{-3} NaOH(aq)

b. 27.8cm^3 of 0.0840mol dm^{-3} HCl(aq)

$$a) \text{ mol} = M L = \frac{0.220 \text{ mol NaOH} / 0.0200 \text{ dm}^3}{\text{dm}^3} = 0.0044 \text{ mol}$$

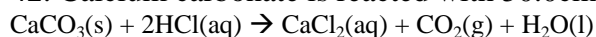
$$b) = \frac{0.0840 \text{ mol} / 0.0278 \text{ dm}^3}{\text{dm}^3} = 0.00234 \text{ mol}$$

41. If 29.70cm^3 of sulfuric acid of concentration 0.2000mol dm^{-3} is required for neutralization of 25.00cm^3 of potassium hydroxide solution, calculate the concentration of the potassium hydroxide solution.



$$\frac{0.2000 \text{ mol H}_2\text{SO}_4 / 0.02970 \text{ dm}^3}{\text{dm}^3} \times \frac{2 \text{ mol KOH}}{1 \text{ mol H}_2\text{SO}_4} \times 0.02500 \text{ dm}^3 = 0.4752 \text{ mol dm}^{-3}$$

42. Calcium carbonate is reacted with 50.0cm^3 of 0.500mol dm^{-3} hydrochloric acid.



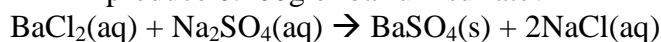
a. What mass of calcium carbonate is required for an exact reaction?

$$\frac{0.500 \text{ mol HCl} / 0.0500 \text{ dm}^3}{\text{dm}^3} \times \frac{1 \text{ mol CaCO}_3}{2 \text{ mol HCl}} \times 100.09 \text{ g} = 1.25 \text{ g}$$

b. What volume of CO_2 , measured at STP, will be produced?

$$\frac{0.500 \text{ mol HCl} / 0.0500 \text{ dm}^3}{\text{dm}^3} \times \frac{1 \text{ mol CO}_2}{2 \text{ mol HCl}} \times 22.4 \text{ dm}^3 = 0.280 \text{ dm}^3 \text{ CO}_2$$

43. What volume (in cm^3) of 0.0100mol dm^{-3} barium chloride must be reacted with excess sodium sulfate to produce 0.100g of barium sulfate?



$$\frac{0.100\text{g BaSO}_4}{233.4\text{g}} \times \frac{1\text{mol BaSO}_4}{1\text{mol BaSO}_4} \times \frac{1\text{mol BaCl}_2}{1\text{mol BaSO}_4} \times \frac{\text{dm}^3}{0.0100\text{mol BaCl}_2} = 0.0428\text{ dm}^3 = 42.8\text{ cm}^3$$

Old IB Multiple Choice

44. What is the total number of atoms in 1.80g of water (H_2O)?

a) 6.02×10^{22}

b) 6.02×10^{23}

c) 1.80×10^{23}

d) 1.80×10^{24}

$$\frac{1.80\text{g H}_2\text{O}}{18.02\text{g}} \times \frac{1\text{mol H}_2\text{O}}{1\text{mol}} \times \frac{6.02 \times 10^{23}\text{molec}}{1\text{molec}} \times \frac{3\text{atoms}}{1\text{molec}} = 6.02 \times 10^{23}$$

45. 88kg of CO_2 contains

a) 2.0mol

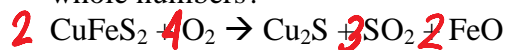
b) 2000mol

c) 0.50mol

d) 3872mol

$$\frac{88\text{kg}}{1\text{kg}} \times \frac{10^3\text{g}}{1\text{kg}} \times \frac{1\text{mol CO}_2}{44.01\text{g}} = 2000\text{mol}$$

46. What is the sum of the coefficients when the following equation is balanced with the smallest possible whole numbers?



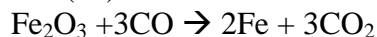
a) 7

b) 8

c) 11

d) 12

47. Iron(III) oxide reacts with carbon monoxide according to the equation:

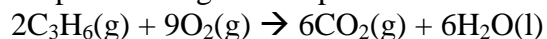


How many moles of iron are produced when 180mol of carbon monoxide react with excess iron(III) oxide?

- a) 120 mol
- b) 180 mol
- c) 270 mol
- d) 360 mol

$$\frac{180 \text{ mol CO}}{3 \text{ mol CO}} \times \frac{2 \text{ mol Fe}}{1} = 120 \text{ mol Fe}$$

48. Propene undergoes complete combustion to produce carbon dioxide and water



What volume of CO_2 is produced when 360cm^3 of propene reacts with 360cm^3 of oxygen at 273K and 1 atm pressure?

- a) 120cm^3
- b) 240cm^3
- c) 540cm^3
- d) 1080cm^3

$$\frac{360 \text{ cm}^3 \text{ C}_3\text{H}_6}{2 \text{ cm}^3 \text{ C}_3\text{H}_6} \times \frac{6 \text{ cm}^3 \text{ CO}_2}{1} = 1080 \text{ cm}^3$$

$$\frac{360 \text{ cm}^3 \text{ O}_2}{9 \text{ cm}^3 \text{ O}_2} \times \frac{6 \text{ cm}^3 \text{ CO}_2}{1} = 240 \text{ cm}^3$$

49. What mass of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ must be used to make up 200cm^3 of a 0.100mol dm^{-3} solution?

- a) 3.16g
- b) 4.96g
- c) 24.8g
- d) 31.6g

$$\text{mol} = \frac{0.100 \text{ mol}}{\text{dm}^3} \times 0.200 \text{ dm}^3 = 0.0200 \text{ mol} \times \frac{248.20 \text{ g}}{1 \text{ mol}} = 4.96 \text{ g}$$

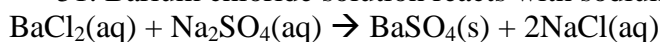
50. 20.00cm³ of potassium hydroxide (KOH) is exactly neutralized by 26.80cm³ of 0.100mol dm⁻³ sulfuric acid (H₂SO₄). The concentration of the potassium hydroxide is:

- a) 0.0670mol dm⁻³
 b) 0.134mol dm⁻³
 c) 0.268mol dm⁻³
 d) 1.34mol dm⁻³

$$\frac{0.100 \text{ mol H}_2\text{SO}_4}{\text{dm}^3} \times \frac{0.02680 \text{ dm}^3}{2 \text{ mol KOH}} \times \frac{1 \text{ mol H}_2\text{SO}_4}{0.0200} = 0.268 \text{ mol dm}^{-3}$$



51. Barium chloride solution reacts with sodium sulfate solution according to the equation



When excess barium chloride solution is reacted with 25.00cm³ of sodium sulfate solution, 0.2334g of BaSO₄ (molar mass 233.4g mol⁻¹) is precipitated. The concentration of sodium ions in the sodium sulfate solution was:

- a) 0.08000mol dm⁻³
 b) 0.04000mol dm⁻³
 c) 0.001000mol dm⁻³
 d) 0.002000mol dm⁻³

$$\frac{0.2334 \text{ g}}{233.4 \text{ g}} \times \frac{1 \text{ mol BaSO}_4}{1 \text{ mol Na}_2\text{SO}_4} \times \frac{1 \text{ mol Na}_2\text{SO}_4}{0.02500 \text{ dm}^3} = 0.0400 \text{ mol dm}^{-3}$$

$$= \frac{0.0400 \text{ mol Na}_2\text{SO}_4}{\text{dm}^3} \times \frac{2 \text{ mol Na}^+}{1 \text{ mol Na}_2\text{SO}_4} = 0.0800 \text{ mol dm}^{-3}$$

52. When potassium chlorate(V) (molar mass 122.6g mol⁻¹) is heated, oxygen gas (molar mass 32.0g mol⁻¹) is produced:



When 1.226g of potassium chlorate(V) is heated, 0.320g of oxygen gas is obtained. The percentage yield of oxygen is:

- a) 100%
 b) 66.7%
 c) 26.1%
 d) 17.4%

$$\frac{1.226 \text{ g KClO}_3}{122.55 \text{ g}} \times \frac{1 \text{ mol KClO}_3}{2 \text{ mol KClO}_3} \times \frac{3 \text{ mol O}_2}{1 \text{ mol O}_2} \times 32.00 \text{ g} = 0.4802 \text{ g}$$

$$\frac{0.320}{0.4802} \times 100 = 66.7\%$$

53. Elemental analysis of a nitrogen oxide shows that it contains 2.8g of nitrogen and 8.0g of oxygen. The empirical formula of this oxide is:

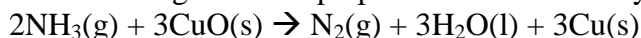
- a) NO
b) NO₂
c) N₂O₃
d) N₂O₅

$$\frac{2.8 \text{ g N}}{14.00 \text{ g/mol}} = 0.2000 \text{ mol} \quad \frac{8.0 \text{ g O}}{16.00 \text{ g/mol}} = 0.5000 \text{ mol}$$

$$\frac{0.2000 \text{ mol}}{0.2} = 1 \times 2 \quad \frac{0.5000 \text{ mol}}{0.2} = 2.5 \times 2$$

PAST IB Paper 2 Questions

54. Nitrogen can be prepared in the laboratory by the following reaction:



If 224 cm³ of ammonia, when reacted with excess copper oxide, produces 84 cm³ of nitrogen, calculate the percentage yield of nitrogen. All gas volumes are measured at STP.

$$\frac{224 \text{ cm}^3 \text{ NH}_3}{2 \text{ cm}^3 \text{ NH}_3} \times \frac{1 \text{ cm}^3 \text{ N}_2}{2 \text{ cm}^3 \text{ NH}_3} = 112 \text{ cm}^3 \text{ N}_2$$

$$\frac{84 \text{ cm}^3}{112 \text{ cm}^3} \times 100 = 75.0\%$$

55. A hydrocarbon contains 88.8% C. 0.201g of the hydrocarbon occupied a volume of 98.3 cm³ at 320K and 1.00x10⁵ Pa.

- a) Determine the empirical formula of the hydrocarbon.
b) Determine the molecular formula of the hydrocarbon.

$$\text{a) } \frac{88.8 \text{ g C}}{12.01 \text{ g/mol}} = 7.397 \text{ mol} \quad \frac{11.2 \text{ g H}}{1.01 \text{ g/mol}} = 11.09 \text{ mol}$$

$$\frac{7.397 \text{ mol}}{7.397} = 1 \times 2 = 2 \quad \frac{11.09 \text{ mol}}{7.397} = 1.5 \times 2 = 3 \quad \text{C}_2\text{H}_3 = 27.0$$

$$\text{b) } M_r = \frac{gRT}{PV} = \frac{0.201 \text{ g} \times 8.31 \text{ J mol}^{-1} \text{ K}^{-1} \times 320 \text{ K}}{1.00 \times 10^5 \text{ Pa} \times 98.3 \times 10^{-6} \text{ m}^3}$$

$$= 54.4 \text{ g/mol} \quad \frac{54.4}{27.0} = 2 \quad \text{C}_4\text{H}_6$$

56. Limestone is impure calcium carbonate. A 1.20g sample of limestone is added to excess dilute hydrochloric acid and the gas is collected; 258cm³ of carbon dioxide was collected at a temperature of 27°C and a pressure of 1.10x10⁵Pa.

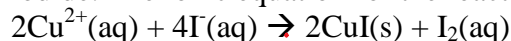


- Calculate the number of moles of gas collected.
- Calculate the percentage purity of the limestone (assume that none of the impurities in the limestone react with hydrochloric acid to produce gaseous products)

$$\text{a) } n = \frac{PV}{RT} = \frac{1.10 \times 10^5 \text{ kg} / 0.258 \text{ dm}^3}{10^{-3} \text{ m}^3 / 8.31 \text{ kg m}^2 / \text{s}^2 \text{ mol K}} \times \frac{1 \text{ dm}^3}{10^{-3} \text{ m}^3} = 0.0114 \text{ mol CO}_2$$

$$\text{b) } \frac{0.0114 \text{ mol CO}_2}{1 \text{ mol CO}_2} \times \frac{1 \text{ mol CaCO}_3}{1 \text{ mol CaCO}_3} \times \frac{100.09 \text{ g}}{1 \text{ mol CaCO}_3} = 1.14 \text{ g} \quad \frac{1.14}{1.20} \times 100 = 95.1\%$$

57. 25.0 cm³ of 0.100mol dm⁻³ copper(II) nitrate solution is added to 15.0 cm³ of 0.500mol dm⁻³ potassium iodide. The ionic equation for the reaction that occurs is:



- Determine which reactant is present in excess.
- Determine the mass of iodine produced.

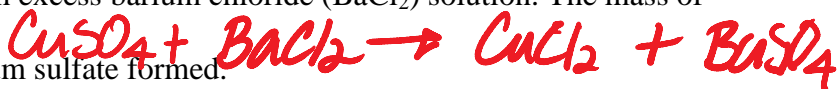
$$\text{a) } \frac{0.100 \text{ mol Cu}^{2+}}{\text{dm}^3} \times \frac{0.025 \text{ dm}^3}{1 \text{ dm}^3} \times \frac{1 \text{ mol I}_2}{2 \text{ mol Cu}^{2+}} = 0.00125 \text{ mol I}_2$$

$$\frac{0.500 \text{ mol}}{\text{dm}^3} \times \frac{0.0150 \text{ dm}^3}{1 \text{ dm}^3} \times \frac{1 \text{ mol I}_2}{4 \text{ mol I}^{-}} = 0.001875 \text{ mol I}_2$$

KI is in excess

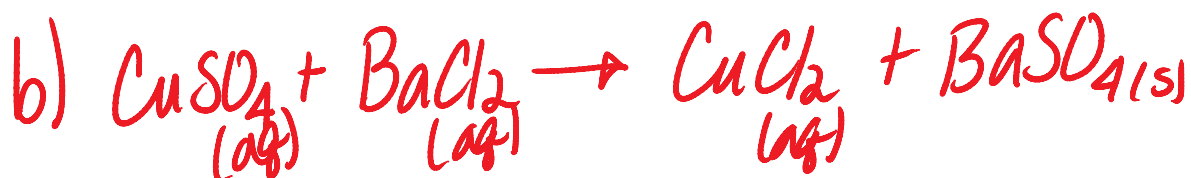
$$\text{b) } \frac{0.00125 \text{ mol I}_2}{1 \text{ mol I}_2} \times \frac{253.8 \text{ g}}{1 \text{ mol I}_2} = 0.317 \text{ g I}_2$$

58. 0.4000g of hydrated copper sulfate ($\text{CuSO}_4 \cdot x\text{H}_2\text{O}$) is dissolved in water and made up to a total volume of 100.0 cm^3 of this solution is reacted with excess barium chloride (BaCl_2) solution. The mass of barium sulfate formed was $3.739 \times 10^{-2} \text{ g}$.



- a) Calculate the number of moles of barium sulfate formed.
 b) Write an equation for the reaction between copper (II) sulfate solution and barium chloride solution to make aqueous copper (II) chloride and barium sulfate
 c) Calculate the number of moles of copper sulfate that reacted with the barium chloride.
 d) Calculate the number of moles of CuSO_4 in 0.4000g of hydrated copper sulfate.
 e) Determine the value of x.

a)
$$\frac{3.739 \times 10^{-2} \text{ g}}{233.39 \text{ g}} \bigg| \frac{1 \text{ mol BaSO}_4}{233.39 \text{ g}} = 1.602 \times 10^{-4} \text{ mol BaSO}_4$$



c)
$$\frac{1.602 \times 10^{-4} \text{ mol BaSO}_4}{1 \text{ mol BaSO}_4} \bigg| \frac{1 \text{ mol BaCl}_2}{1 \text{ mol BaSO}_4} = 1.602 \times 10^{-4} \text{ mol BaCl}_2$$

d)
$$\frac{1.602 \times 10^{-4} \text{ mol BaCl}_2}{1 \text{ mol BaCl}_2} \bigg| \frac{1 \text{ mol CuSO}_4}{1 \text{ mol BaCl}_2} = 1.602 \times 10^{-4} \text{ mol CuSO}_4 \times 10$$

$$= 1.602 \times 10^{-3} \text{ mol CuSO}_4$$

e)
$$\frac{1.602 \times 10^{-3} \text{ mol CuSO}_4}{1 \text{ mol}} \bigg| \frac{159.6 \text{ g}}{1 \text{ mol}} = 0.2557 \text{ g CuSO}_4$$

$$\text{g H}_2\text{O} = 0.4000 - 0.2557 = 0.1443 \text{ g}$$

$$\frac{0.1443 \text{ g H}_2\text{O}}{18.015 \text{ g}} \bigg| \frac{1 \text{ mol H}_2\text{O}}{18.015 \text{ g}} = 0.008010 \text{ mol H}_2\text{O}$$

$$\frac{0.008010 \text{ mol H}_2\text{O}}{0.001602 \text{ mol CuSO}_4} = 5 \quad \text{CuSO}_4 \cdot 5 \text{ H}_2\text{O}$$